CHARM MESON PRODUCTION AND DECAYS IN E687

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ABSTRACT

Recent results on charmed meson production and decays from the Fermilab experiment E687 are presented. The E687 detector studies high-energy photon-Be interactions using a large aperture multiparticle magnetic spectrometer with excellent vertex, particle identification and calorimetric capabilities. The average triggered photon energy is approximately 220 GeV. Experimental results on correlations from $D\overline{D}$ pairs are used to study production dynamics and the effects of charm quark dressing. The high statistics sample of 10^5 reconstructed charmed particles allows a systematic investigation of charmed meson decays and lifetimes: we report here a preliminary measurement of CP violation in the $D^0 - \overline{D^0}$ system and a study of D_s decays.

1. $D\overline{D}$ Pair Correlation Study

We have analyzed a sample of fully reconstructed $D\overline{D}$ pairs in the E687 experiment [1] using decay modes of D mesons which are copiously produced with high acceptance, namely: $D^+ \rightarrow K^-\pi^+\pi^+$, $D^0 \rightarrow K^-\pi^+$, $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$, and their charge conjugates. The principal cutting tool used to isolate the D signals is the normalized decay flight distance l/σ_l. The $D\overline{D}$ signature is shown in fig. 1.

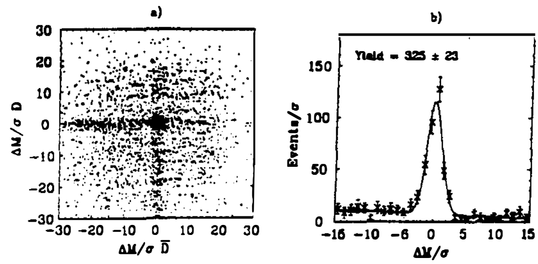


Fig. 1 a) Scatter plot of the normalized mass of the detached D candidates versus the normalized mass of the detached recoil $\overline{D}$ candidates. b) Normalized mass distribution of the D candidates when the recoiling $\overline{D}$ candidate is reconstructed within 2 σ of the nominal mass. ΔM is the difference between the reconstructed mass and the Particle Data Group value for the candidate and σ is the error on the reconstructed mass.

Comparisons of experimental distributions are made to Monte Carlo predictions based on the Lund Model [2]. In this model charm quarks are produced by the interaction of beam photons and target nucleons through photon-gluon fusion. The nucleon structure-function set was taken from ref. 3 (the structure-function set dependence was found to be negligible). The intrinsic target gluon p_t was assumed to be gaussian with a width of 0.44 GeV/c. Quark fragmentation into hadrons was assumed to proceed according to the Lund string fragmentation model. Correlations were studied using the fully reconstructed $D\overline{D}$; in fig. 2.a,b the raw transverse momentum-squared distribution and rapidity difference of the $D\overline{D}$ pairs are plotted. In fig. 2.c the invariant mass distribution of the $D\overline{D}$ pair, $M_{D\overline{D}}$, is compared to that from the Monte Carlo. These results indicate good agreement between the model and data; only the $p_t^2(D\overline{D})$ distribution is significantly harder in the data sample.

The acoplanarity angle $\Delta\phi$, defined as the azimuthal angle between the D and $\overline{D}$ momentum vectors in the plane transverse to the photon direction, is plotted in fig. 2.d: both the data and Monte Carlo accumulate near π. A value $\Delta\phi = \pi$ corresponds to back-to-back $D\overline{D}$ production, as expected in the context of photon-gluon fusion. Resolution, charm-quark dressing, and effects due to intrinsic gluon p_t spreading cause deviations from $\Delta\phi = \pi$. Our data sample distribution tends to be significantly smeared from $\Delta\phi = \pi$ and is somewhat flatter than in the Monte Carlo model.

2. Analysis of CP violation in the $D^0 - \overline{D^0}$ system

A CP violation signature would be an asymmetry in the decay rate of $D^0 \rightarrow K^-K^+$ and its CP conjugate $\overline{D^0} \rightarrow K^-K^+$. Within the Standard Model CP asymmetries in the decays

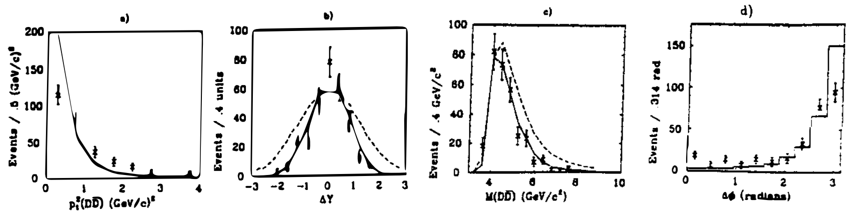


Fig. 2 Fully reconstructed $D\overline{D}$ pairs: a) $p_t^2(D\overline{D})$ distribution; b) $D\overline{D}$ rapidity difference $(Y_D - Y_{\overline{D}})$; c) $D\overline{D}$ pair invariant mass. The points with error bars are the background-subtracted data, the solid curves represent the Monte Carlo predictions including apparatus acceptance and resolution effects, while the dashed curves represent parent distributions in the absence of acceptance and resolution effects; d) acoplanarity distribution $\Delta\phi$ compared to the Monte Carlo (solid histogram)

$D^0 \to K^- K^+$ are estimated to be at most a few 10^{-3} [4]. The mass distributions for $D^0 \to K^- K^+$ and $\overline{D^0} \to K^- K^+$ for 50 % of the E687 statistics are shown in fig. 3.a,b: the sign of the bachelor pion in the D^* decay tags the neutral D as either a D^0 or a $\overline{D}^0$.

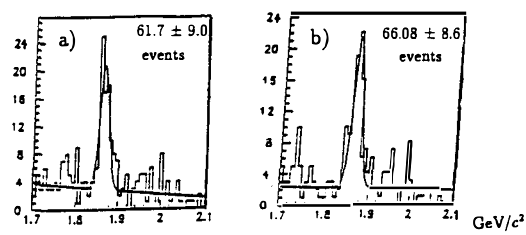


Fig. 3 Signal and fit for a) $D^0 \to K^- K^+$ from D^{*+} and b) $\overline{D^0} \to K^- K^+$ from D^{*-}.

After normalizing the observed signals to the ratio of our measured D^{*-} vs. D^{*+} cross sections we obtain a value $A < 0.184$, 90% C.L. for the direct CP violation asymmetry, to be compared with the only previous measurement: $A < 0.45$, 90% C.L. by the E691 experiment [5].

3. The charmed strange meson $D_s^\pm$

Although there has been a systematic study of the D^+ and D^0 hadronic decays, this has not yet been possible in the case of the D_s^+. Experimental measurements are limited to a few exclusive channels and are affected by large errors. We present a preliminary result for the relative branching ratios D_s^+ and D^+ decays into the $\pi^+\pi^-\pi^+$ final state. The resulting $\pi^+\pi^-\pi^+$ mass distribution is shown in fig. 4.a. There are clear peaks for both the D^+ and D_s^+. The peak around 1.75 GeV is due to $D^+ \to K^-\pi^+\pi^+$ where the kaon is misidentified as a pion. The branching ratios are measured relative to the decay modes $D_s^+ \to \phi\pi^+$ and $D^+ \to K^-\pi^+\pi^+$, shown in fig. 4.b and c respectively. Our preliminary results are $B(D_s^+ \to \pi^+\pi^-\pi^+)/B(D_s^+ \to \phi\pi^+) = 0.33 \pm 0.08 \pm 0.04$ and $B(D^+ \to \pi^+\pi^-\pi^+)/B(D^+ \to K^-\pi^+\pi^+) = 0.035 \pm 0.006 \pm 0.0044$, which are consistent with previous measurements [6].

The lifetime of the D_s^+ meson has not been measured as precisely as the lifetimes of the D^0 and D^+ primarily because of its lower production rate. We report a new precise

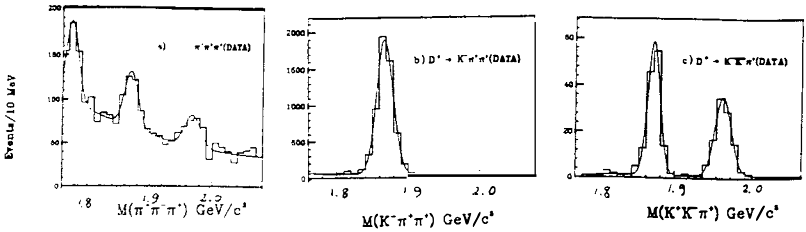
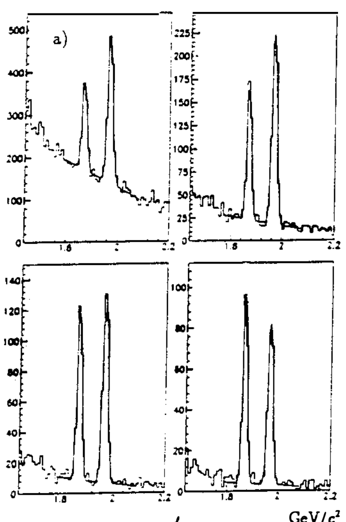


Fig. 4 Mass distributions for a) 3π final state; b) $D^+ \to K^-\pi^+\pi^+$ and c) $D_s^+ \to \phi\pi^+$

measurement based on 900 fully reconstructed D_s^+ decays to $\phi\pi^+$ (see fig. 5.a). The final D_s^+ lifetime measurement is thus 0.472 $\pm$ 0.020(stat.) $\pm$0.010 (syst.) ps. In fig. 5.b our result is compared to other measurements.



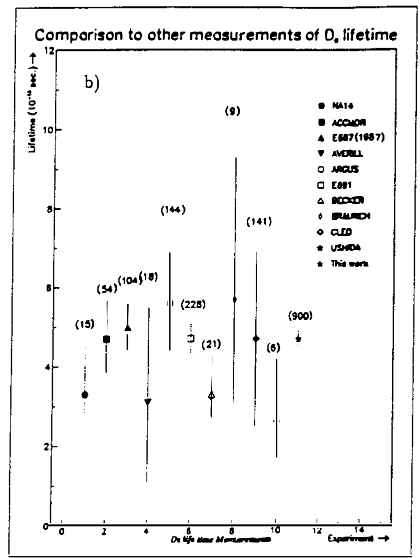


Fig. 5 a)$\phi\pi$ invariant mass distribution for various l/σ_l cuts; b) comparison with other experiments (the number of events on which each measurement is based is given in brackets)

The large number of D_s^+ mesons allows a study of decay dynamics. We have looked at the $K^-K^+\pi^+$ final state (see fig. 6.a) to evaluate the resonant and non-resonant contributions to the D_s^+ signal. The ability to observe the KKπ non-resonant mode without the benefit of the resonance-selection cuts is a measure of the effectiveness of using the vertex separation cuts to reduce background. The dominance of the two-body modes in this decay of the D_s^+ is shown clearly in the Dalitz plot of fig. 6.b where the ϕ and $\overline{K^{*0}}$ bands are evident. The D^+ Dalitz plot of fig. 6.c for the same decay shows a larger non-resonant contribution. The more highly non-resonant nature of the D^+ seems to be confirmed by the decay $D^+ \to K^-\pi^+\pi^+$, whose mass distribution and Dalitz plot are shown in fig. 7.a and b respectively. A fit to the

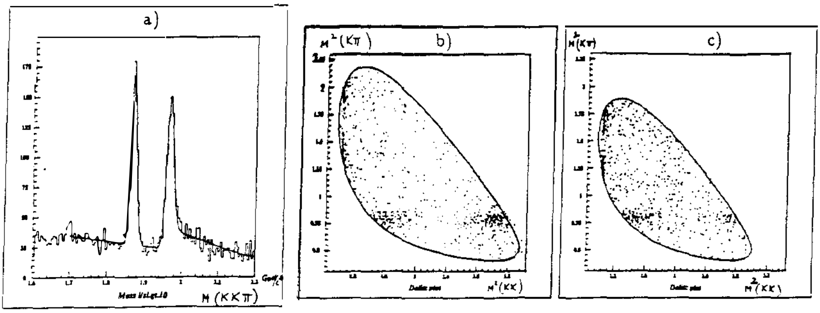


Fig. 6 a) $K^-K^+\pi^+$ mass distribution; b) $D_s^+ \to K^-K^+\pi^+$ Dalitz plot; c)$D^+ \to K^-K^+\pi^+$ Dalitz plot

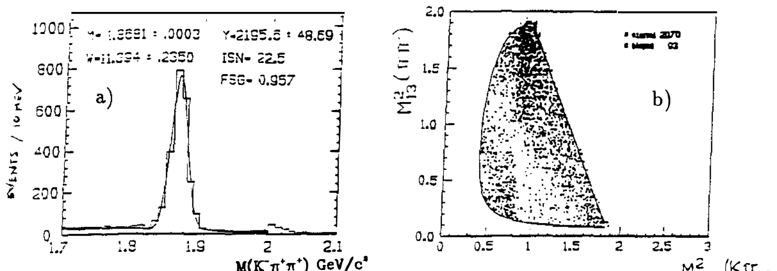


Fig. 7 a) $K^-\pi^+\pi^+$ mass distribution; b) $D^+ \to K^-\pi^+\pi^+$ Folded Dalitz plot

Dalitz plots will allow extraction of the different contributions of the substructures present in the decays and the evaluation of the relative amplitude phases.

4. Conclusions

E687 reconstructed 10^5 charm particles and will play a crucial role in understanding charm physics. The spectrometer used in E687 will be upgraded to enable it to accumulate 10^6 fully reconstructed charm events. The physics will involve high-precision studies of D semileptonic decays, QCD studies of double D events, a measurement of the absolute branching fraction for the D^0, searches for D^0 mixing, CP violation, rare and forbidden decays, fully leptonic decays of the D^+ and a systematic investigation of charm baryons and their lifetimes.

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